

THE SPATIO-TEMPORAL EVOLUTION OF THE AVERAGE DROUGHT AFFECTING GEORGIA

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INTRODUCTION

At the end of June 1988, portions of northern Georgia were experiencing a meteorological drought with a recurrence interval in excess of 100 years (Soulé and Meentemeyer, 1989a). This drought persisted through the autumn and winter months of 1988-1989, causing extremely low lake and well levels. Specific drought events are often studied (e.g. Cook, et al. 1988) as well as a state's or region's drought climatology (e.g. Eder and Davis, 1987; Henry and Dicks, 1984; van Bavel and Carreker, 1957). Nevertheless little is known about temporal and spatial development of the average drought affecting a specific area or region.

The primary purpose of this study is: (1) to determine whether droughts affecting Georgia originate in the state versus expanding into the state from another region; and (2) to compare the temporal and spatial development of Georgia's average drought with moisture patterns across the entire 48 United States. Finally we examine the possibility that droughts originating in other portions of the country can be used to predict drought in Georgia. Results from this work should prove useful to individuals or organizations responsible for drought contingency planning in Georgia.

DATA

Within the last twenty years, the most frequently used measure of regional drought severity in United States climatological studies has been the Palmer Drought Severity Index (PDSI) (Palmer, 1965). To aid in the dissemination of comparable drought information, we also use the PDSI as the primary basis for analysis of mesoscale drought patterns.

The PDSI is based on a soil water balance methodology which matches moisture supply from precipitation against demand by potential evapotranspiration. The index ranges from about -7 to +7, where negative numbers represent moisture conditions below normal, positive numbers represent abnormally wet periods, and zero is normal. The PDSI has a

moderate rate of response to precipitation and evapotranspiration and has been termed an index of meteorological drought. The details of this approach have been reviewed by Karl (1983).

Monthly PDSI values for each of the 344 Climatic Divisions in the United States for the 55 year period 1931-1985 were read from data tapes supplied by the National Climatic Data Center (NCDC). In addition to PDSI values, Palmer's Z-index, which represents agricultural drought, and Palmer's Hydrologic Drought Index (PHDI) were read from the tapes to help confirm the starting and ending points for a drought event. Both the Z-index, a fast responding drought index, and PHDI, a slow responding index, are derived from the original Palmer (1965) model and produce values comparable to the PDSI.

METHODS

As a first step, climatic divisions representative of conditions in Georgia were selected. The Northwestern, South Carolina Division (#3802) is used to represent conditions in northern Georgia, especially the northeast. This division was shown in earlier work (Soulé and Meentemeyer, 1989b) to be most representative, or typical of the month to month patterns of moisture conditions in the Southeastern states. The Central Georgia Division (#905) was selected to represent the core and remaining portions of the state.

The Statistical Analysis System (SAS) was used to sort the monthly drought indices and to select drought events. Our definition of a drought sequence (event) follows that of Diaz (1983) who defined a drought sequence as any span of three or more months with $PDSI \leq -2.0$ (moderate drought). A "major" drought was defined as six consecutive months.

To insure that the true beginning of a drought sequence was included in our analysis, this rule was relaxed to include any span of three consecutive months where any of the three Palmer indices were ≤ -1.0 (mild drought). A "major" drought was defined by six consecutive months with Z-index, PDSI or PHDI values ≤ -1.0 . By these criteria the Northwest, SC division had 24 drought sequences in the 55 year study period, with an average duration of

11.5 months and 15 "major" (≥ 6 month) sequences with a mean duration of 16.6 months. The Central, GA division experienced 30 drought sequences with an average duration of 9.6 months and 17 "major" sequences with a mean length of 14.1 months.

A primary purpose of this study is to determine the average national moisture conditions (including drought) at the time that Georgia is experiencing a major drought. PDSI values representing the first month of the average major drought event were calculated for each climatic division in the United States by taking the mean PDSI value from the first month of all major drought sequences identified in the historical record at Climatic Divisions 3802 and 905 ($N=17$ and $N=15$). This same procedure was followed for months two to six to show the temporal progression in moisture conditions across the entire country when Georgia is experiencing a drought. Only the first six months of drought events were analyzed because there are few droughts of long duration.

The SAS output of mean monthly PDSI values was then interfaced with Golden Graphics (SURFER) mapping routines to interpolate the division means and produce a series of maps of average PDSI values for months one, two, etc. These map sequences display the average temporal and spatial development of moisture conditions in the U.S. at the time that a drought is occurring in Georgia.

RESULTS

Figure 1 presents a sequence of three maps of mean PDSI values for months 1, 3 and 5 based on the 15 major drought events experienced in Division 3802. The maps illustrate moisture conditions in month 1, 3, and 5. When droughts start, much of the Southern Appalachian Piedmont and mid-Atlantic area is experiencing PDSI values of less than -0.5. But it is noteworthy that portions of the Northern Great Plains region west to Washington State already have well developed droughts in this month exceeding -1.0. At this time most of the southwestern part of the country is experiencing above average moisture conditions. By the second month the drought in Division 3802 greatly intensifies to mean values greater than -1.5.

In the third to fifth months the area of drought increases and becomes more intense but remains concentrated in the southern states exclusive of Florida. The maps of standard deviations of PDSI values (not shown) shows low variation over most of the drought area in the SE, which indicates that on average considerable temporal and spatial autocorrelation exists for these droughts. The highest standard deviations occur in regions that are essentially out of phase with Georgia's

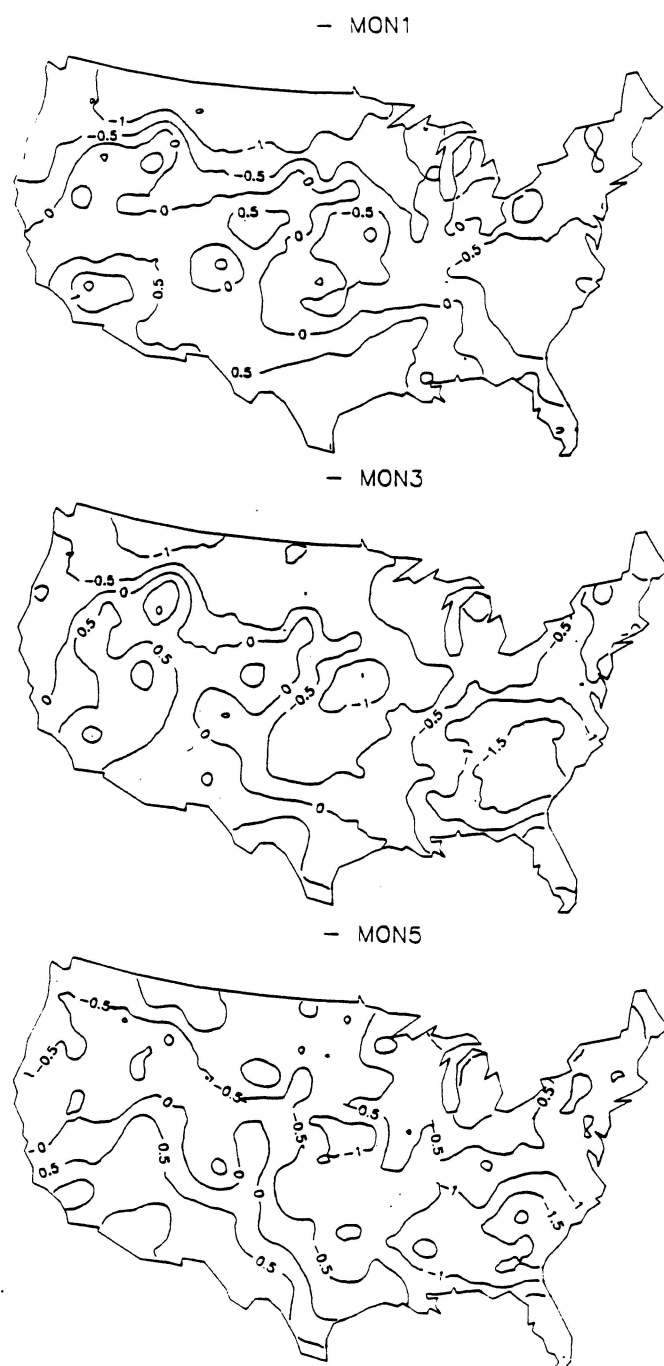


FIGURE 1. PDSI VALUES FOR MONTHS 1, 3, AND 5 OF THE AVERAGE MAJOR DROUGHT, BASED ON THE 15 MAJOR DROUGHT SEQUENCES RECORDED AT THE SOUTHWEST, SOUTH CAROLINA CLIMATIC DIVISION, 1931-1985.

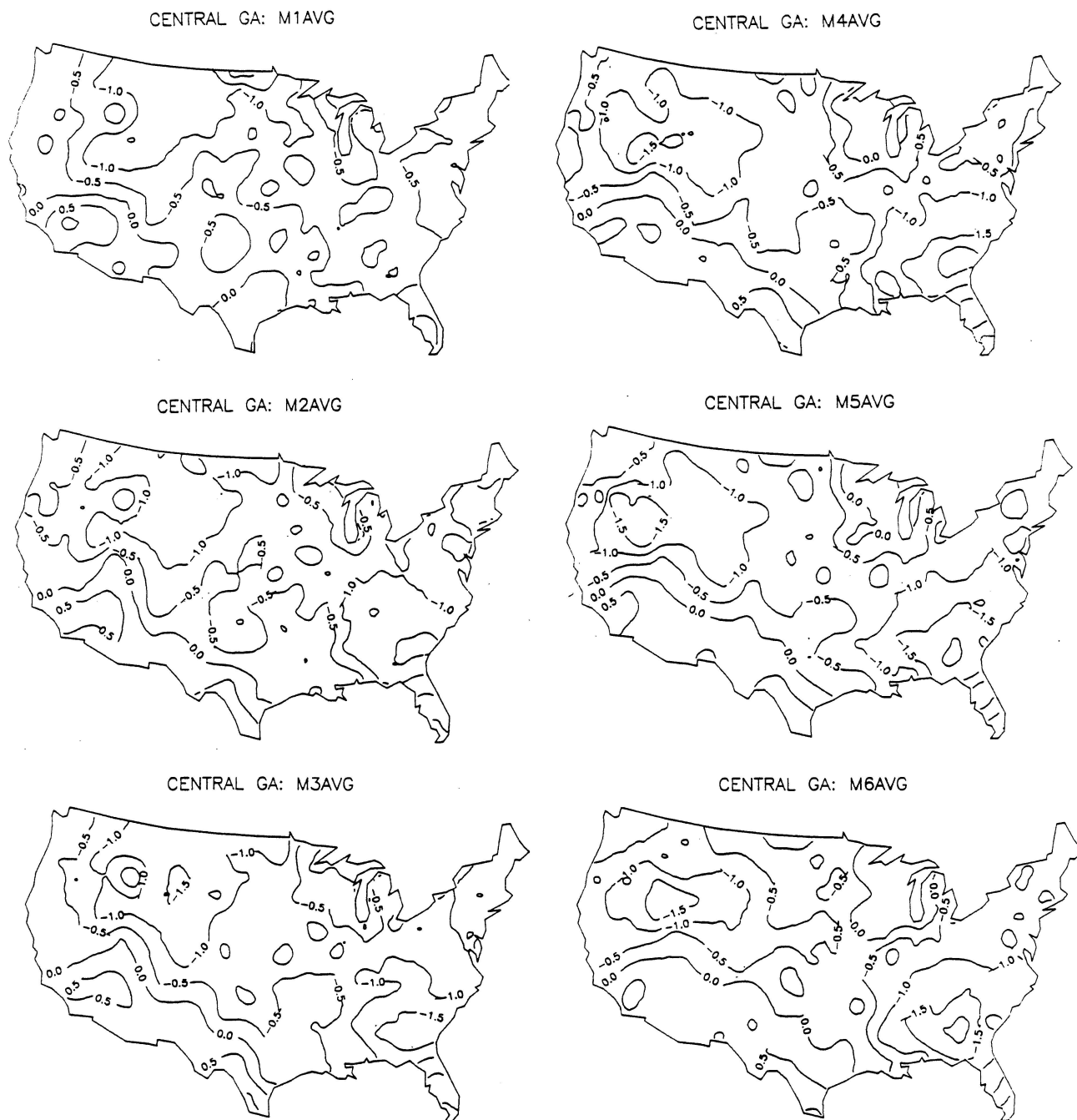


FIGURE 2. PDSI VALUES FOR MONTHS 1 TO 6 OF THE AVERAGE MAJOR DROUGHT, BASED ON THE 17 MAJOR DROUGHT SEQUENCES RECORDED AT THE CENTRAL, GEORGIA CLIMATIC DIVISION, 1931-1985.

droughts (e.g. Western and Southwestern areas). By the sixth month the drought region in which Georgia is embedded shrinks in area and intensity and is reduced to between -1.0 and -1.5. The upper Great Plains area has, however, experienced by this time a decrease in intensity to values between -0.5 and -1.0.

Figure 2 shows a second set of maps for months 1 through 6 based on droughts which have started in Central Georgia (Division 9C5). As expected, these maps bear many similarities to those presented for Division 3802. When a drought starts in Central Georgia, droughts are already well developed in the Northern Plains and Northern Rocky Mountain regions. At this time the extreme southwestern area has above normal moisture conditions. From months two through six the drought persists in the Southeastern states exclusive of Florida. In fact these results support the finding of Henry and Dicks (1984) that moisture conditions in Florida tend to be out of phase with conditions in Georgia.

These results suggest that it is probably worthwhile to search for spatial teleconnections in drought evolution. Rigorous tests will need to be conducted to determine whether moisture conditions in regions that tend to be in phase with Georgia's droughts (e.g. the upper Great Plains and Northern Rocky Mountain area) or out of phase (e.g. the Southwestern area) can be used as indicators of drought in Georgia. In addition, more work needs to be performed on the mechanisms which generate these patterns.

Other patterns need investigation. As an indirect result of this study, we observed that droughts across most of the 48 states are in their early phases associated with above average temperatures, i.e. with higher potential evapotranspiration rates. Thus droughts involve much more than simple departures from normal precipitation.

CONCLUSIONS

It can be argued that most historical droughts affecting Georgia have been unique events, each caused by a particular combination of synoptic climatic controls. The methodology employed in this study was designed to help look for the underlying signals or patterns to these "unique" events. We found that droughts in Georgia tend on average to be initiated in the state or in the proximate region, especially in the Appalachian piedmont region. While this result is at least partially an artifact of the methodology employed, when the same methodology is applied to other regions of the United States, the resulting patterns can deviate substantially from both the theoretical and methodological expectations (Soulé 1989).

We also found that when droughts begin in Georgia, moisture conditions are generally well below normal in the upper Great Plains and

Northern Rocky Mountain region. The southwestern states are largely out of phase with Georgia as they tend to have above average moisture conditions when Georgia is experiencing a drought.

Rigorous tests of regional teleconnections are needed before it is possible to state with assurance that regional drought precursors can be identified.

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